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U.S. DEPARTMENT OF AGRICULTURE • Economic Research Service

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AGRICULTURAL ECONOMICS RESEARCH VOL. 23, NO. 1, JANUARY 1971

Empirical Determination of Optimum Quality Mix

By Masao Matsumoto and Ben C. French

Changes in the distribution of an agricultural commodity among quality classes may affect the total revenue obtained from a given quantity of product. Growers and marketing firms need to consider the best mix of qualities as well as the best level of output. This paper describes an approach to the empirical problem of selecting, from several alternative feasible mixes of qualities, the one which would yield the maximum net revenue. The paper focuses on a single attribute and a single commodity but the concepts and methodology used can be extended readily to other quality attributes and other commodities. Key words: Product quality, multiproduct demand analysis, brussels sprouts, price discrimination.

Most agricultural commodities are produced and marketed in a variety of quality classes defined by attributes such as size, color, shape, texture, sweetness, blemishes, percentage of defects, and the like. Since consumer preferences for quality are variable, changes in the distribution of a commodity among such classes may affect the total revenue obtained from a given quantity of product. The mix of qualities is determined to a considerable extent by biological and growth processes which are beyond the direct control of management. However, it can be influenced, at a cost, by cultural practices and by the handling, grading, and packaging practices employed by processors and shippers. In formulating production plans, growers and marketing firms thus need to consider not only how much to produce, but the best mix of qualities in view of both revenue and cost effects. Firms or industry groups are also faced with the problem of determining how quality classes shall be defined, including the number of separate classes to be distinguished. The present analysis takes the structure of quality classes as given.

This paper describes an approach to the empirical problem of selecting from among the alternative feasible mixes of qualities, the particular mix that may be expected to yield the largest net revenue. We illustrate the approach for a specific commodity—frozen brussels sprouts—and a single quality attribute, the size of the individual sprouts. The concepts and methodology may be extended readily to other quality attributes and commodities.

The focus of the analysis is on the potential gain in net returns to the industry (both growers and processors) rather than to an individual firm or a particular industry subgroup. The ultimate division of any net gains from altered quality distribution would depend on the nature of grower supply response and the structure of competition in the raw product market.

Achievement of an improved or optimum quality position implies the development of a raw product pricing system that reflects final product demands back to growers in a manner consistent with the optimizing adjustments. This requires that there be a clearly defined relationship between final product quality and raw product quality. Given this relationship—which is direct in the case of size attributes—an appropriate raw product pricing system would reflect the differences in marginal production costs involved in shifting the quality mix among classes. The final level of raw product prices would depend on the characteristics of grower supply and competition among freezers.

Theoretical Framework

An appropriate theoretical framework for analyzing the quality mix problem may be derived from the theory of the multiproduct discriminating monopolist. If we think of each quality variation as a different product, or alternatively as a different market outlet, the problem may be viewed as the determination of the optimum distribution of total sales among markets or products with interrelated demands. While many microtheory texts deal with some aspects of the problem, perhaps the best mathematical treatment for our purposes is to be found in Waugh (*5*).[1] We shall follow his general line of development, except that costs associated with varying quality mixes are given explicit treatment in our model.[2]

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[1] Italic numbers in parentheses indicate items in the References, p. 9.

Assume that the production of an agricultural commodity is distributed among K quality classes. The price received for the ith quality depends not only on the quantity in that class, but the quantity in each other class, plus other variables such as income and competing products which may shift the entire level of demand. The total quality demand system is described by K quotations, one of each quality class. Holding shift variables such as income constant and assuming linear relationships (as in our empirical analysis) a typical demand equation would have the form

$$(1) \qquad P_i = b_{i0} + \sum_{i=1}^{K} b_{ij} Q_j \qquad i, j = 1, 2, \ldots K$$

where P is price, Q is quantity, and b_{i0} and b_{ij} are coefficients of the demand equations.

The gross revenue equation, obtained by multiplying the price in each quality class by the quantity in that class and summing, may be written as

$$(2) \qquad GR = \sum_{i=1}^{K} Q_i P_i = \sum_{i=1}^{K} Q_i \left(b_{i0} + \sum_{j=1}^{K} b_{ij} Q_j \right).$$

To obtain the net revenue equation we subtract the total cost from the gross revenue. For this purpose, the unit cost may be decomposed into two parts, a constant part $\bar{c}$, common to all quality classes, and a variable part, c_i, which varies among quality classes. In general, the c_i's may vary as functions of quantities in all classes and these functions may have nonlinear forms.[3] For simplicity, we shall regard the c_i's as constants (they are so estimated in the empirical analysis). The basic conceptual model is not essentially altered by this simplification.

With these considerations, the net revenue equation is expressed as follows:

$$(3) \quad NR = \sum_{i=1}^{K} Q_i \left(b_{i0} + \sum_{j=1}^{K} b_{ij} Q_j \right) - \sum_{i=1}^{K} c_i Q_i - \bar{c} Q$$

where Q is the total quantity to be sold, obtained by summing over all classes.

We wish to find the values of Q_i which will maximize (3) for any given value of Q. To solve, we form a Lagrangian function, set the first partial derivatives equal to zero, and solve the resulting linear equations for values of Q_i as a function of Q.

$$(4) \quad L = \sum_{i=1}^{K} Q_i \left(b_{i0} + \sum_{j=1}^{K} b_{ij} Q_j \right) - \sum_{i=1}^{K} c_i Q_i + \bar{c} Q + \lambda \left(\sum_{i=1}^{K} Q_i - Q \right).$$

$$(5) \quad \frac{\partial L}{\partial Q_i} = b_{i0} + \sum_{j=1}^{K} (b_{ij} + b_{ji}) Q_j - c_i + \lambda = 0.$$

$$(6) \quad \frac{\partial L}{\partial \lambda} = \sum_{i=1}^{K} Q_i - Q = 0.$$

Solving for λ gives the value of marginal net returns which, for a maximum, must be the same for all quality classes.

To assure a maximum we must have, in addition to conditions (5) and (6), $d^2 L < 0$ subject to

$$\sum_{i=1}^{K} dQ_i = 0.$$

The value of $d^2 L$ will be negative definite if the principal bordered minors of the Hessian determinant formed from L alternate in sign, starting with the minor formed by the first three rows and columns > 0. (See Lloyd (*3*) or Yamane (*6*).)

Note that in solving equations (5) and (6) we are not required to know the value of $\bar{c}$ (the costs common to all sizes). We need only the marginal costs (the c_i's) associated with altering the quality distribution.

With no other restraints, the solution procedure outlined above could give negative values for some of the Q_i's. If this should happen, either of two alternatives may be considered. In some cases it may be clear that the values of the Q_i's that were negative will always assume the minimum amount permitted. Quantities for these classes therefore may be set at zero (or some proportion of Q) and the problem solved again with the added restrictions as equalities. More generally, restraints may be added of the form $Q_i \geqslant 0$ for all i (or some $Q_i \geqslant a_i Q$) and a solution obtained as a quadratic programming problem. This, or course, could be done at the outset. The first procedure was followed in the frozen brussels sprouts model since it was evident that a proper solution would be obtained by this method.

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[2] The problem of determining optimum product quality for a firm producing a single quality of product has been well developed by Dorfman and Steiner (*2*). They introduce a continuously variable index of quality into both the demand and cost functions of the firm and determine the conditions for joint optimization of quality and price for a given quantity. They note that a range of qualities would be offered if the market consists of groups of consumers with differing quality demands. However, they do not develop this case explicitly, nor do they deal with the case where the firm (or industry) produces a spectrum of qualities as a consequence of biological factors involved in the production process.

[3] General theoretical considerations involved in incorporating product quality into the production function are well developed in Dano (*1*). However, he does not extend his analysis to the joint product case found in agriculture.

Demand Interrelationships for Quality Attributes

Estimation of the parameters of the system of demand equations requires continuous series of data pertaining to prices and quantities in each quality class. For frozen brussels sprouts such data have, for the most part, never been published in any form. Consequently, it was necessary to acquire data directly from the records of processing firms in the industry.

Monthly sales and price data by size class were compiled from records of freezers covering the years 1961 and 1962.[4] These firms packed about 55 percent of all the frozen brussels sprouts marketed by California firms during these 2 years and the data are believed to be representative of the California industry's experience. California freezers accounted for about 94 percent of U.S. frozen brussels sprouts production in these years. Data covering additional periods would have been desirable but lack of complete historical records in the firms surveyed, plus the sheer physical difficulties involved in the compilations, required that the survey be limited to a 2-year period.

Frozen brussels sprouts vary considerably in size, with the smaller sizes commanding a price premium. The brussels sprouts trade typically quotes prices by a range of count per pound which we have grouped into three classes: large (less than 25 per pound), medium (25 to 40 per pound), and small (over 40 per pound). There is a further breakdown by type of package—retail (1 pound or less) and institutional (over 1 pound). Thus, our basic data series consists of 24 monthly observations on prices and sales for three sprout size classes and two container classes.

The basic model to be estimated expresses the average monthly price in each size and container category as a linear function of the monthly quantity sold in each category. Nonlinear forms are of course equally possible. With many variables and cross-relationships, it is difficult to determine the nature of existing curvilinearity and to estimate any except the simple log form. Preliminary graphic explorations suggested that linear estimates would provide reasonable approximations within the range of the data.

In view of the relatively short period involved, the annual values of competing products and income were omitted.[5] Quantities were expressed in total rather than per capita terms. Monthly carlot unloads of fresh brussels sprouts in 41 U.S. cities were included as a variable to allow for both seasonal shifts and the competitive effects of the fresh commodity. Initial regression estimates suggested the presence of a trend in some equations, possibly due to the omission of income and other competing products. Thus, a time trend also was added. Since there are six size-container classes, we have six equations each of the form:

$$(7)\, P_{it} = b_{i0} + b_{i1}Q_{RLt} + b_{i2}Q_{RMt} + b_{i3}Q_{RSt} + b_{i4}Q_{ILt} + b_{i5}Q_{IMt} + b_{i6}Q_{ISt} + b_{i7}Q_{Ft} + b_{i8}T + V_{it}$$

where

Q is quantity in 1,000 pounds;
R refers to retail size containers;
I refers to institutional size containers;
L, M, S are sizes of sprouts—large, medium, and small;
P is average price (cents per pound);
Q_F is monthly carlot unloads of fresh brussels sprouts in 41 U.S. cities;
T is a time trend, varying from 1 to 24;
$i = 1, 2, \ldots 6$, indicates a particular size-container category (e.g., $P_{1t} = P_{RLt}$);
$t = 1, 2, . . 24$, indicates the number of the monthly observation; and
v is an unexplained disturbance.

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[4] This phase of the analysis was initiated in the early 1960's at the request of the members of the brussels sprouts industry. The survey of processors was completed in 1963 and preliminary analysis finished shortly thereafter. However, because of diverting assignments, the final phases were not completed until much later. A very limited amount of data has been obtained for more recent years and serves as a basis for checking the previous results. The major conclusions reached with the data appear to hold, at least approximately, for more current conditions.

[5] Data pertaining to monthly sales of most competing frozen vegetables are not available. Explorations of monthly shipment data for fresh vegetables, except fresh brussels sprouts, failed to produce promising indicators of regular shifts in the monthly demand for frozen sprouts.

The choice of statistical procedure to use in estimating the parameters of this equation system involved both theoretical and empirical considerations. Since we are dealing with monthly observations our initial approach was to view the demand equations as part of a simultaneous system. That is, monthly quantities sold were regarded as determined simultaneously with monthly prices. This view required that we specify short-run supply equations and then estimate the parameters of the entire demand-supply system by simultaneous equations procedures.

Supply equations were formulated in which the monthly quantities of sprouts marketed, by size class, were expressed as linear functions of prices and beginning monthly inventory levels in each size class. The latter were adjusted for normal seasonal variation. Beginning inventories were viewed as predetermined variables, thus producing a system in which the coefficients of the demand equations were identified.

The parameters of this system of equations were estimated by two-stage least squares. The results were quite unsatisfactory, both by usual statistical criteria and in terms of the expected signs and magnitudes of the equation coefficients. This may have been due in substantial part to the very poor quality of our data pertaining to monthly quantities of each size category held in cold storage.[6] In any case, it was necessary to abandon this procedure and turn to other methods of estimation.

Our second approach was to apply ordinary least squares directly to the estimation of the parameters of each structural equation. This method is justified if processors establish quantities to be sold each month without regard to current price. We would not argue that processor plans and adjustments are so completely inflexible, but processors may well be more concerned with orderly movement of total stocks and honoring buyer commitments than with adjustments to monthly price variations. Under these circumstances the degree of bias may be "reasonably" small.

The results of our initial application of ordinary least squares, although superior to the two-stage least squares model, still had some coefficients with positive signs or of low statistical significance. The main difficulty appeared to be that the sample was too small, the range of observations too limited, and the intercorrelation among quantity variables too high to isolate the separate effects on price of each of the six alternative size-container classes in each equation. To reduce the intercorrelation problem and the number of coefficients to be estimated we combined several of the variables in each equation.

The most satisfactory results were obtained by a formulation which related price in each size-container class to the quantity in that class and the total quantity in all other classes. The regression equations are summarized in table 1. All of the coefficients are consistent with theoretical expectations—i.e., they are all negative and each price is affected more by changes in its own quantity than by quantities in other classes. Sales of fresh brussels sprouts (Q_F) had a highly significant effect on prices of medium sprouts and a somewhat significant effect on prices of medium sprouts in retail containers. The coefficient of Q_F was of quite low statistical significance in the equations for large sprouts and for small institutional-container sprouts. Therefore, Q_F was omitted in the final regressions for these classes. Possibly the extreme size classes are less sensitive to the fresh market. The trend factor clearly was not significant for institutional containers and so was omitted from the latter set of equations. For large sprouts in institutional containers, the coefficient of $Q_T - Q_{IL}$ was small and of very low statistical significance so it was dropped from this equation—i.e., its coefficient is regarded as zero.

Cost of Altering the Quality Mix

The primary means by which the size distribution of sprouts may be changed is through varying the time interval between harvests or the timing of once-over machine harvest. The major cost factors involved are the loss in yield with decreased size and the higher per pound harvesting cost with smaller sizes. The distribution could also be altered by simply discarding some of (say) the larger sprouts. To maintain production at a given level, the discarded sprouts would have to be replaced by quantities produced on additional acreage. This appeared to be excessively expensive compared with other procedures considered and so was rejected as an alternative.

With an inelastic demand, discarding quantities in lower quality classes would, of course, increase total revenue. In this case, the f.o.b. freezer demand is elastic, so revenue would be reduced. Moreover, our purpose is to determine the optimum quality mix for any given quantity, leaving open the determination of the total amount to be produced.

At the freezing level, the main cost influence is in the trimming operation. Trimming time per sprout remains

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[6] Published data on monthly cold storage holdings do not indicate the quantities held in each size category. These values were estimated on the basis of total stocks and the proportions packed initially in each size class. Such estimates could be very inaccurate.

Table 1.—Demand relationships for frozen brussels sprouts by size-container class: Final selected regressions

Dependent variable	Constant term	Explanatory variables[a]									R[c]	d[d]
		Q_{RL}	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}	$Q_T - Q_i$[b]	Q_F	T		
	regression coefficients and t-ratios[e]											
P_{RL}	25.197	–.00136 (1.721)						–.00045 (2.421)		–.03450 (3.689)	.773	1.68
P_{RM}	27.887		–.00051 (1.710)					–.00027 (1.403)	–.00252 (2.294)	–.01249 (1.795)	.801	1.20
P_{RS}	29.914			–.00235 (2.756)				–.00024 (1.116)	–.00182 (1.487)	–.01628 (1.959)	.773	1.75
P_{IL}	22.827				–.00334 (4.152)						.663	2.76
P_{IM}	26.234					–.00132 (3.049)		–.00027 (1.942)	–.00406 (4.865)		.945	2.39
P_{IS}	27.064						–.00636 (3.906)	–.00013 (1.458)			.732	1.85

[a] See text for explanation of symbols.

[b] $Q_T = Q_{RL} + Q_{RM} + Q_{RS} + Q_{IL} + Q_{IM} + Q_{IS}$. Q_i refers to the variable treated as dependent.

[c] Coefficient of multiple correlation.

[d] Durbin-Watson statistic. The hypothesis of no positive serial correlation of error terms is not rejected at the 5 percent significance level for the first, fourth, fifth, and sixth equations. The value of d falls in the indeterminant range for the second and third equations. There is a suggestion of negative serial correlation for the fourth equation.

[e] Figures in parentheses are t-ratios.

essentially constant, regardless of sprout size. Thus, cost per pound is greater for the smaller sizes.

Our studies of these operations indicated that with conventional multiple-harvest cultural practices, shifting 1 pound of sprouts from the large to the medium size would increase the combined production and processing cost by roughly 0.9 cent per pound.[7] Shifting a pound from the medium to the small class would increase costs by another 0.9 cent per pound. Since we have no direct observations to indicate how costs of shifting size distributions might be affected by one-over machine harvest and the introduction of new varieties, the cost figures should be regarded only as rough approximations. However, they are satisfactory for purposes of illustration and seem close enough to permit a tentative evaluation of potential gains or losses from changes in distribution.

Since our focus is primarily on size distribution, we have assumed that the average observed price difference between container types for the same sprout size reflects the difference in cost of packaging in retail and institutional containers. This was 1.73 cents per pound higher for retail packages (for all sprout sizes) during the period for which data were obtained.

The c_i's of our conceptual model—equations (3), (4), and (5)—may be derived by adding the estimated differences in costs to c, the unit cost common to all sizes. Thus, the total cost of production and processing may be expressed as

$$(8)\quad TC = \bar{c}Q + 1.73\,Q_{RL} + 2.63\,Q_{RM} + 3.53\,Q_{RS} + 0.0\,Q_{IL} + 0.9\,Q_{IM} + 1.8\,Q_{IS}\,.$$

Recall that, with total quantity (Q) constant, $\bar{c}$ drops out of the marginal revenue equations.

Note that with costs expressed as a linear function of the Q_i (i.e., $TC = aQ + \sum_{i=1}^{K} a_i Q_i$) we can always rewrite the equation as $TC = (a + a_j)\,Q + \sum_{i=1}^{K} (c_i - c_j)\,Q_i$. The coefficient for Q_j will thus be zero. In (8), $Q_{IL} = Q_j$ and $\bar{c} = a + a_j$.

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[7] For details of the cost estimates see Matsumoto (*4*).

Revenue Effects

A monthly gross revenue equation may be obtained by multiplying the equation in table 1 by the quantity corresponding to the dependent variable and summing equations.[8] A net revenue equation is derived by subtracting equation (8) from the gross revenue equation. Following the procedure outlined in (3) to (6), the revenue-maximizing quality mix may be determined for each month as a function of the total quantity of frozen sprouts to be sold during the month, the monthly sales of fresh sprouts, and the value of the trend factor. The basic decision facing the industry, however, is not how to allocate predetermined monthly sales among quality classes (although eventually this must be done), but how much to produce in each quality class. Since production decisions are made annually rather than monthly, we need an annual revenue function. This is obtained by summing the monthly revenue equations over 12 months.

Given the annual total quantity of sprouts to be sold and the expected seasonal pattern of sales of fresh-market sprouts, the annual revenue function may be solved for the optimum allocation of quantities to each quality class for each month. The monthly quantities then may be summed to obtain the annual production mix. Our basically simple conceptual problem involving three quality classes (and two container classes) thus expands, in application, to the determination of the optimum allocation of a given annual quantity among 72 economic classes (12 months, three qualities, and two container types).

While this type of problem clearly can be handled without great difficulty on a computer, even as a quadratic programming problem, it is perhaps asking quite a bit of our limited empirical model, especially since it does not include consideration of inventory cost, customer relations, and expectation formation which might influence the distribution pattern. It also unnecessarily complicates the development of the points we wish to illustrate. To focus more directly on the quality mix problem—that is, the best distribution of qualities for a given quantity of annual industry production—we shall introduce some simplifications which enable us to abstract from the seasonal pattern of distribution, while still providing a basis for some rough generalizations.

Specifically, we shall hold the level of fresh marketings at the mean value for the period of the study and set T at zero.[9] This gives us a set of typical demand equations, summarized in table 2, which illustrate the essential characteristics of the interrelated demand struc-

Table 2.—Simplified demand model for frozen brussels sprouts by size-container class ($Q_f = 58.6$ and $T = 0$)

Dependent variable	Constant term	Explanatory variables					
		Q_{RL}	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}
		equation coefficients					
P_{RL}	25.197	–.00136	–.00045	–.00045	–.00045	–.00045	–.00045
P_{RM}	27.379	–.00027	–.00051	–.00027	–.00027	–.00027	–.00027
P_{RS}	29.807	–.00024	–.00024	–.00235	–.00024	–.00024	–.00024
P_{IL}	22.827				–.00334		
P_{IM}	25.996	–.00027	–.00027	–.00027	–.00027	–.00132	–.00027
P_{IS}	27.064	–.00013	–.00013	–.00013	–.00013	–.00013	–.00636

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[8] Since prices are expressed in cents per pound and quantities in 1,000-pound units, the value obtained by this procedure must be multiplied by 1,000 to obtain the true value of revenue (in cents).

[9] Recall that the trend variable was inserted primarily to allow for effect of possible demand shifters, such as income or competing products, which were not included as specific variables in the demand model. In this sense, the trend has no significance beyond the study period. The choice of zero for the trend value was a matter of convenience in formulating the illustrative demand and revenue equations. If T had been set at 12 or 24, rather than zero, the demand for retail containers would have been reduced relative to the institutional containers and the demand for the retail large class would have been reduced relative to the medium and small. These small shifts would slightly alter the solutions to the problem of optimum distribution in favor of medium sizes, but the major conclusions would remain essentially the same.

ture and which may be easily converted to annual demands and revenues by a factor of 12. The total quality mix determined with these simplified equations would not be identical with a solution based on the more complex summation of monthly allocations, but we would expect it to be reasonably close.[10]

Although we are ultimately interested in the net revenue equations, we shall first briefly explore the gross revenue function since it may be used to develop some useful information pertaining to effects of changes in size allocation without immediate reference to cost. This had considerable merit in view of the rough nature of our cost-size-of-sprout relationships.

To extract the desired information we first take the total differential of the gross revenue equation, obtaining

$$(9) \qquad dGR = \sum_{i=1}^{6} \frac{\partial GR}{\partial Q_i} dQ_i \ .$$

The marginal revenues, $\partial GR/\partial Q_i$, are then calculated for each quality class with quantities held at the average levels for the sample of observations. The gross revenue effects of small shifts in allocation between pairs of classes (i and j) are obtained by setting $dQ_i = 1$, $dQj = -1$, and all other $dQ_r = 0$.

Table 3 summarizes these values. It indicates, for example, that shifting 1,000 pounds from the retail-large to the retail-small class would increase gross revenue by $45.25. These marginal gains or losses may be compared with expected marginal costs to suggest something about desirable directions and potential gains from change.

If our estimates of transfer costs between classes are subtracted from the values in table 3, we obtain the net revenue estimates shown in table 4. With these adjustments, the marginal gain in shifting 1,000 pounds from the retail-large to the retail-small class, for example, is reduced to $27.25, still a significant gain. As expected in view of our assumptions concerning cost differences, the potential gains or losses from shifts between container types for like sizes is quite small in all cases. In general, table 4 suggests that net revenue could be increased by a program aimed at shifting quantities from large into medium and small categories. However, it does not indicate how much should be shifted or what the final distribution should be. For this purpose, we need to make additional calculations.

The distribution among quality classes which maximizes the value of the net revenue function was obtained as indicated in equations (4), (5), and (6). The b coefficients of the revenue equation are contained in table 2 and the c coefficients are given in equation (8). The initial solution produced negative values for the quantities in the large size classes. Consequently, it was

Table 3.—Changes in gross revenue associated with shifting 1,000 pounds of frozen brussels sprouts from one size-container class to another[a]

1,000-pound decrease in	1,000-pound increase in				
	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}
	dollars				
Q_{RL}	25.58	45.25	–24.42	10.19	24.20
Q_{RM}		19.67	–50.00	–15.39	– 1.38
Q_{RS}			–69.67	–35.06	–21.05
Q_{IL}				34.61	48.62
Q_{IM}					14.01

[a]Starting with average sample quantities in each class.

Table 4.—Changes in net revenue associated with shifting 1,000 pounds of frozen brussels sprouts from one size-container class to another[a]

1,000-pound decrease in	1,000-pound increase in				
	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}
	dollars				
Q_{RL}	16.58	27.25	– 7.12	18.49	23.50
Q_{RM}		10.67	–23.70	2.21	6.92
Q_{RS}			–34.37	– 8.76	– 3.75
Q_{IL}				25.61	30.62
Q_{IM}					5.01

[a]Starting with average sample quantities in each class.

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[10] The solution by months would involve reduced total frozen-sprout sales in months of large fresh-market sales. In months of smaller frozen-sprout sales, the optimum solution would require relatively larger percentages of sprouts in small sizes and relatively smaller percentages in medium sizes, with large sizes at the minimum permitted. The weighted average quality mix for all months would be close to, but not necessarily the same as, the mix obtained with an average level of fresh market sales.

necessary to impose restrictions which would guarantee that quantities in all classes would be greater than or equal to zero. A solution could have been obtained by quadratic programming procedures. However, since it was clear that the quantity in the "large" class would be the minimum permitted, restrictions were imposed as equalities and solutions were obtained as before, except with the added restrictions. All other unrestricted quantities remained positive with this solution.

Table 5 shows the optimal distribution for the total quantity of average monthly sales observed during the same period. Three alternative solutions are presented, each involving different restrictions on the quantity of large sprouts. Solution 1 imposes only the restriction that the quantity in each class must be greater than or equal to zero. Because it may be unreasonable to assume that the quantity in large sizes can be reduced to zero (without abandoning parts of the production), we have computed two additional solutions which require that at least (a) 5 percent and (b) 10 percent of the production will fall in the large class. To focus entirely on the size allocation problem, solutions 2 and 3 also restrict the distribution between retail and institutional containers to the proportions observed during the sample period.

The three solutions give similar results. They leave the proportions allocated to medium sizes with little change, reduce the quantity in large sizes, and increase the allocation to smaller sprouts. Solution 1 increases the California industry revenue, compared with the value obtained by applying sample proportions to the estimated revenue equations, by \$158.000 per year, solution 2 by \$145,000, and solution 3 by \$104,000. Comparisons with actual average revenue during the sample period gave similar results. These potential gains, obtained by expanding sample values to reflect total industry experience, are in the order of 1-1/2 to 1 percent of gross revenue.

The optimal allocation proportions in table 5 pertain only to the quantities sold during the sample period, 1961-62. As total sales change, so do the optimal allocations among size classes. By leaving the value of Q (the total quantity) unspecified, a more general solution can be obtained in which the quantities in each quality

Table 5.—Actual and optimal distribution of sprout sizes for the 1961-62 sample quantity of sales.

Size-container class	Actual distribution	Optimal distributions		
		Solution 1[a]	Solution 2[b]	Solution 3[c]
	proportion of total			
Large:				
Retail	.096	.000	.023	.046
Institutional	.114	.000	.027	.054
Total	.210	.000	.050	.100
Medium:				
Retail	.488	.473	.483	.449
Institutional	.154	.204	.153	.142
Total	.642	.677	.636	.591
Small:				
Retail	.126	.270	.267	.263
Institutional	.022	.053	.047	.046
Total	.148	.323	.314	.309

[a] $\frac{Q_L}{Q_T} \geqslant 0.$

[b] $\frac{Q_L}{Q_T} \geqslant .05$ and $Q_{RL} = .457Q_L$, $Q_{RM} = .759Q_M$, $Q_{RS} = .852Q_S$.

[c] Restrictions same as for solution 2 except $\frac{Q_L}{Q_T} \geqslant .10$.

class are expressed as linear functions of Q.[11] They may be converted to a percentage basis by dividing through by Q. These solutions suggest that as industry total quantities increase, the proportions allocated to medium sizes should be increased and the allocation to the smaller sizes slightly decreased, with large sizes at the minimum permitted.

Concluding Comments

The results of our study are encouraging. They demonstrate that it is possible to develop an empirically quantifiable model which may aid agricultural groups in formulating programs aimed at achieving the best—or at least a better—mix of qualities. The approach used would be appropriate for many quality attributes other than size.

The major limitation of this and possibly similar studies that might be attempted is in the data, especially the price and sales data. Although the demand model developed is significant in a statistical sense and is consistent with theoretical expectations, substantially more observations would be desirable to build confidence in the precision and generality of the estimates.

For many commodities priced at shipping points or central markets there may be fairly long series which could be tabulated from market news data. For most processed commodities, price and sales data unfortunately are not published by quality class, if at all. Commodity groups interested in this type of analysis could initiate data collection programs through their trade associations. For storable commodities, this would need to include information on the quality mix of inventory holdings, as well as sales. Costs associated with quality changes would, of course, have to be obtained by special studies in each case.

The potential industry gains suggested by this study appear quite modest—in the neighborhood of 1 percent of gross revenue. Our guess would be that potential gains for other commodities and quality attributes would be found to be similarly modest. For many industry groups, however, the absolute magnitude could be substantial and such gains may be well worth striving for, especially in periods of tight margins and increasing costs.

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[11] Examination of the original unrestricted solution indicated that as crop size increased, the optimum quantity in the "large" class would eventually become positive. However, this would occur only for crop sizes far larger than any yet observed. Quantities in other categories would always remain positive.

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Measuring Efficiency in the Beef-Pork Sector by Price Analysis

By John E. Trierweiler and James B. Hassler

The price structure of the beef-pork sector from the retail level back to the primary production level is evaluated in order to identify areas of inefficient performance. Results indicated efficient pricing performance between the slaughter and the retail levels. Results between the ranch and feedlot levels indicated a weak and distorted price structure. This appeared to be due to the inability of the price system to serve both as a mechanism of trade and as a signal for the organization and timing of future production. Key words: Price performance, efficiency, space, time, form.

To the casual observer, the pricing activities of the livestock-meat industry might appear chaotic. Such an impression would be easy to develop with the multitude of products and byproducts, seasonal and general price variations, and the complicated logistics involved in producing, distributing, and storing the industry's output.

In recent years critics have questioned the ability of the competitive structure of the livestock-meat industry to perform efficiently as a mechanism of trade and a guide for production. This paper describes a study which disclosed that there may be some justification for such a viewpoint. The objectives of the study were to evaluate specific price relationships of the beef-pork sector and to delineate areas of disorderly or inefficient production and marketing performance from the resulting price evidence.

Before any judgment on efficiency can be rendered, a valid standard must be postulated as a basis for comparison. The standard used in this analysis is the long-run competitive equilibrium specification for rates of production and marketing which result in price levels and differentials in space, time, and form that are consistent with minimal production, distribution, and storage costs. A rigorous analysis of the marketing system for beef and pork would involve a microeconomic appraisal of least-cost equilibrium transfers from each level of the system to the next. However, a cruder price analysis based on assuming approximately constant transfer costs (for 1957-66, the study period) will prove workable and still might provide a basis for comparative evaluation of production and marketing performance. Although some losses occur through this simplification, gains result from greater clarity and manageability, hopefully without significantly distorting the interrelations of the major forces involved in product pricing.

Relationships between prices and quantities for the beef-pork sector, from primary production at the farm or ranch to final consumption as beef and pork, were analyzed. Theoretical estimation techniques are discussed briefly. Primary concern is presentation and evaluation of statistical and economic results to ascertain areas of inefficient performance in the industry.

Beef and Pork at Retail

The analysis assumes that domestic civilian quantities consumed during the period were equivalent to production less changes in storage inventories, import-export balances, and military consumption. Price levels were assumed to be flexible and dependent on the predetermined supply volumes that had to clear the market. Separate price functions for beef and pork were fitted using the simple least-squares multiple regression technique. The usual tests of goodness of fit were applied.

The beef and pork equations estimated quarterly for the United States from 1957 to 1966 in linear form are:

$$(1)\ P_1 = 78.33983 - \underset{(0.34372)}{2.72784}\,X_1 - \underset{(0.75145)}{1.45827}\,S_1$$

$$- \underset{(0.74229)}{0.93549}\,S_2 + \underset{(0.78934)}{2.08688}\,S_3 + \underset{(0.00423)}{0.03673}\,X_3$$

$$R^2 = 0.693$$

(2) $$P_2 = \underset{}{132.28963} - \underset{(0.59060)}{1.54889\, X_1} - \underset{(0.53225)}{5.02065\, X_2}$$

$$- \underset{(1.43948)}{6.96960\, S_1} - \underset{(1.66744)}{11.05847\, S_2} - \underset{(0.83342)}{8.43848\, S_3}$$

$$+ \underset{(0.00723)}{0.02559\, X_3} \qquad R^2 = 0.806$$

where

P_1 = retail beef price (cents per pound).
P_2 = retail pork price (cents per pound).
X_1 = quarterly per capita consumption of beef and veal (carcass equivalent).
X_2 = Quarterly per capita consumption of pork (carcass equivalent).
X_3 = per capita disposable income at annual rates (dollars), deflated by the index of consumer prices (1957-59 = 100).
S_1 = dummy variable for seasonal variation in winter quarter.
S_2 = dummy variable for seasonal variation in spring quarter.
S_3 = dummy variable for seasonal variation in summer quarter.

The signs of all the coefficients in the estimating equations agree with economic theory. The standard errors of the coefficients are in parentheses. Results of the *t*-test in the retail beef price equation indicate that per capita consumption of beef and disposable income are significant at the 0.01 level, while seasonal variation in summer is significant at the 0.05 level. Although seasonal variations in winter or spring are not significant in this equation, they were included on the grounds that they removed some of the interaction through time within the estimating system. Results of the *t*-test in the retail pork equation indicate that all variables except per capita consumption of beef and veal are significant at the 0.01 level, while consumption of beef and veal is significant at the 0.05 level. The independent variables in the beef equation explain 69 percent of the variation in retail beef price, while the independent variables in the pork equation explain 81 percent of the variation in retail pork prices. The coefficients of determination are significant in both equations at the 0.01 level. The standard errors of estimate are 1.65 cents per pound above and below the mean for the beef equation, and 2.82 cents per pound for the pork equation.

Both the beef and pork equations were estimated in linear form. Therefore, the property of nonconstant elasticity, a feature of linear demand functions, presents a problem for the selection of meaningful points for quantification. The following quarterly consumption rates and annual income rates were selected for evaluating the elasticities of the beef-pork estimates: $X_1 = 27.5$, $X_2 = 16.25$, and $X_3 = 2{,}350$. These values appear consistent for the present and near future. In the quantity dependent form, the beef and pork demand functions are:

(3) $$X_1 = 28.71863 - 0.36659\, P_1 - 0.53459\, S_1$$
$$- 0.34294\, S_2 + 0.76503\, S_3 + 0.01346\, X_3$$

(4) $$X_2 = 26.34910 - 0.30850\, X_1 - 0.19918\, P_2$$
$$- 1.38819\, S_1 - 2.20260\, S_2 - 1.68076\, S_3$$
$$+ 0.00510\, X_3$$

The most influential factor in retail prices of beef and pork is per capita consumption of beef. The price elasticities of demand are – 1.19 for beef and – 0.84 for pork. Although not a precise measure of consumer demand, the values obtained suggest an elastic response in the quantity of beef consumed to changes in the retail price of beef, while pork consumption is inelastic in response to changes in the price of pork.

The income elasticity of demand, a measure of the change in the consumption rate corresponding to a change in personal disposable income, was 1.15 for beef and 0.74 for pork. This would indicate, other things being equal, that per capita consumption of beef would increase at a faster rate than pork with increases in personal disposable income. Past evidence has tended to indicate that consumers prefer beef to pork (*1*, pp. 70-77).[1] If trends continue into the future with rising personal income, beef producers will benefit more than pork producers.

In the estimated function for retail beef prices it was found that per capita consumption of pork was not statistically significant. However, per capita consumption of pork as well as beef was found to be significant in the retail price of pork. This appears contrary to past analyses of these two products (*4*, pp. 12-13). The following argument may help to explain these results: With the rapid rise in personal income during the last decade, variations of beef and pork prices were offset by the income effect. When the price of beef increased relative to pork price, consumers preferred to maintain their consumption of beef and accept a temporary decrease in real income rather than substitute pork for beef. Conversely, during periods of increased pork prices relative to beef price, consumers shifted from pork to beef consumption. The argument maintains that once a level of beef consumption has been attained, the consumer will not retreat to a less preferred good for small changes in retail price. Some caution should be exercised, however, before accepting this relationship too readily.

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[1] Italic numbers in parentheses indicate items in the References, p. 17.

The coefficients for seasonal variation shift the demand curve to the right or left, to reflect differences between average quantities consumed in the fall quarter and those consumed during the other seasons, at the same price. The coefficients of seasonal variation for beef indicate that the consumption rates decrease 0.53 pound per capita in winter and 0.34 pound in spring, and increase 0.77 pound in summer, relative to fall quarter levels. Fall consumption is contained in the constant term of the estimate. In the pork estimates, per capita consumption decreases below the fall quarter rate by 1.39 pounds in winter, 2.20 pounds in spring, and 1.68 pounds in summer.

Wholesale-Retail Beef Price Relationships

The price system at the wholesale level serves as a mechanism for distributing beef carcasses and semi-dressed pork cuts from meatpackers to retail outlets. Beef is generally quoted on a whole-carcass basis for carlot loads. Pork, on the other hand, is quoted as wholesale cuts, at less than carlot loads, in the form of semidressed loins, boston butts, hams, bacon slabs, etc. Because of the aggregation problem and the complexity of the wholesale pork market, quantification of the performance between the wholesale and retail markets was not attempted in this study. The study did, however, measure the industry performance between the retail and the slaughter levels.

Price relationships between levels were estimated for the period from 1957 to 1967 by months as follows:

$$(5)\quad P_{w_1} = 9.96677 + \underset{(0.03842)}{0.74830\,P_1} - \underset{(0.82630)}{12.95590\,W_r} - \underset{(0.15065)}{0.60680\,X_1} \qquad R^2 = 0.804$$

where

P_{w_1} = price of Choice beef carcasses 601 to 700 pounds at Chicago (dollars per hundredweight).

P_1 = retail price of beef and veal (cents per pound).

W_r = wage rate for food and kindred product workers (dollars per hour).

X_1 = first difference in per capita consumption between quarters ($X_t - X_{t-1}$).

The signs on the first two coefficients agree with economic theory. Standard errors of the coefficients are in parentheses. The standard error of estimate is \$1.49 per hundredweight.

The coefficient for the retail beef price is 0.75, reflecting the approximate carcass yield between the wholesale and retail levels for Choice beef carcasses. The variable for wage rates represented the cost of preparing carcass beef for retail sales. The coefficient implies a cost of \$13 per hundredweight, reflecting the retail cost of cutting and trimming, advertising, overhead, transportation, labor, and locker shrinkage. The coefficient for the difference in per capita consumption represented the delay in adjustment to consistency between wholesale and retail prices (*6*, pp. 19-20). This results in alternate periods of gain or loss at the wholesale or retail level, depending on increasing or decreasing supplies of beef which create short-period "buyer" or "seller" marketing conditions. In general, the above estimating equation indicates good price performance between the wholesale and retail levels.

Beef Carcass Prices, by Grade and Weight

The following relationships estimated the horizontal price performance at the wholesale level between various weights and grades of beef carcasses. Choice grade carcasses, 601 to 700 pounds, were chosen as the base. Theoretically, if the price mechanisms were performing efficiently, the regression coefficient should be near 1 (reflecting relative retail cut yield rates), and the constant term equal to the average weight or grade differential for the given comparison. The equations were estimated as follows:

$$(6)\quad P_{w_2} = 0.99811 + \underset{(0.02068)}{0.95982\,P_{w_1}} \qquad r^2 = 0.948$$

$$(7)\quad P_{w_3} = 0.08362 + \underset{(0.03456)}{0.96180\,P_{w_1}} \qquad r^2 = 0.868$$

$$(8)\quad P_{w_4} = 0.49322 + \underset{(0.02231)}{0.93471\,P_{w_1}} \qquad r^2 = 0.937$$

$$(9)\quad P_{w_5} = 4.54895 + \underset{(0.02629)}{0.84482\,P_{w_1}} \qquad r^2 = 0.897$$

where

P_{w_1} = wholesale price of 601- to 700-pound Choice beef carcasses at Chicago (dollars per hundredweight).
P_{w_2} = wholesale price of 701- to 800-pound Choice beef carcasses at Chicago (dollars per hundredweight).
P_{w_3} = wholesale price of 801- to 900-pound Choice beef carcasses at Chicago (dollars per hundredweight).
P_{w_4} = wholesale price of 601- to 700-pound Good beef carcasses at Chicago (dollars per hundredweight).
P_{w_5} = wholesale price of 501- to 600-pound Good beef carcasses at Chicago (dollars per hundredweight).

The standard errors are 0.75, 1.25, 0.81, and 0.95 per hundredweight, respectively.

The relationships are sufficiently strong to suggest efficient price performance between the various weights and grades at the wholesale level. The regression coefficients are slightly less than 1 for the two Choice and heavy Good grade carcasses, while the constant terms are slightly greater than zero. This implies very little weight or grade differential value for these carcasses. The coefficient for the 501- to 600-pound Good grade carcasses is considerably lower at 0.84, while the constant term is higher at 4.54. The distortions in the estimated functions could have resulted from the narrow range in the data during the time period tested and the usual flattening fit from simple least squares. These two factors combined to tip the regression lines, yielding regression coefficients which were less than might be expected while at the same time forcing the constant terms to intersect the axis higher than expected. The above results, however, are adequate for forecasting purposes, and would probably yield estimates with errors of no more than 1 or 2 percent.

Slaughter-Wholesale Beef Price Relationships

In addition to examining the slaughter-to-wholesale level, this section links the slaughter-to-retail structure. The price of Choice steers, 900 to 1,100 pounds, was used as the base price. The relationships were estimated using monthly prices from 1957 to 1966 as follows:

$$(10)\quad P_{c_1} = -4.35784 + \underset{(0.01482)}{0.68975\,P_{w_1}} + \underset{(0.01702)}{0.19009\,t} \qquad R^2 = 0.951$$

$$(11)\quad P_{c_1} = -3.06539 + \underset{(0.02768)}{0.52421\,P_1} - \underset{(0.59443)}{6.27350\,W_r} \qquad R^2 = 0.760$$

where

P_{c_1} = price of Choice slaughter steers, 901 to 1,100 pounds, at Omaha (dollars per hundredweight).
P_{w_1} = price of Choice beef carcasses, 601 to 700 pounds, at Omaha (dollars per hundredweight).
P_1 = retail price of beef and veal (cents per pound).
t = annual trend (1957 = 1).
W_r = wage rates for food and kindred product workers (dollars per hour).

The signs of all of the coefficients agree with economic theory. The standard errors of the estimate are $0.049 and $1.07 per hundredweight, respectively.

The coefficient for carcass beef price in the slaughter-to-wholesale equation indicated a liveweight-to-carcass yield of 69 percent. The coefficient for annual trend indicated an increase in the slaughter prices of 19 cents per hundredweight per year. Secular trends in plant efficiency and more direct selling could support this result.

In the second equation, the coefficient for retail price indicates a liveweight-to-retail yield of 52 percent. This yield rate appears to be consistent with yield rates found in the earlier analyses, from wholesale to retail and slaughter to wholesale.

Slaughter-Retail Pork Price Relationships

Since the relationship between wholesale and retail prices for the pork industry was not estimated, the relationship between slaughter and retail prices is examined in this section. Theoretically the price margin between the two levels should reflect the retail pork yield, minus the cost of processing and distribution, plus the value of any byproducts salvaged in the slaughter-to-retail movement. The relationship was estimated as follows:

$$(12)\quad P_{h_1} = -12.77266 + \underset{(0.02180)}{0.55540\,P_2} - \underset{(0.72409)}{1.34337\,W_r} \qquad R^2 = 0.855$$

where

P_{h_1} = price of No. 1-3 butcher hogs at Omaha, 220 to 240 pounds (dollars per hundredweight).

P_2 = retail price of pork excluding lard (cents per pound).

W_r = wage rates for food and kindred product workers (dollars per hour).

The signs of the coefficients agree with economic theory. The standard error of estimate is \$1.35 per hundredweight.

The uncorrelated marketing costs of processing, storage, cutting and trimming, etc., plus the value of salvaged byproducts and lard, are contained in the constant term. Costs correlated with wage rates are represented in the coefficient for wage rates. Their combined net value suggested a net cost of approximately \$15.50 per hundredweight of live hog. This value seems reasonably close to present industry standards. The coefficient on retail price accurately indicates a 55 percent yield rate for live to retail conversion (excluding lard). Overall, the estimating equation suggests efficient marketing performance for the pork industry from the slaughter to the retail level.

Slaughter Cattle Prices by Weights, Grades, and Classes

Theoretically, the relationships between prices for the various weights, grades, and classes of beef cattle should reflect the relative yields, and the value of premiums or discounts for weight, grade, or class. In the analysis, Choice steers at Omaha, 900 to 1,100 pounds, were chosen as the base. The relationships were estimated as follows:

$$(13)\quad P_{c_2} = -0.56483 + \underset{(0.01143)}{1.02122}\,P_{c_1} \qquad r^2 = 0.985$$

$$(14)\quad P_{c_3} = 0.35661 + \underset{(0.02002)}{0.89833}\,P_{c_1} \qquad r^2 = 0.945$$

$$(15)\quad P_{c_4} = -2.26548 + \underset{(0.02712)}{1.14684}\,P_{c_1} \qquad r^2 = 0.938$$

$$(16)\quad P_{c_5} = 0.81024 + \underset{(0.01787)}{0.93793}\,P_{c_1} \qquad r^2 = 0.959$$

$$(17)\quad P_{c_6} = 0.90758 + \underset{(0.02561)}{0.85018}\,P_{c_1} \qquad r^2 = 0.903$$

where

P_{c_1} = price of Choice slaughter steers at Omaha, 900 to 1,100 pounds (dollars per hundredweight).

P_{c_2} = price of Choice slaughter steers at Omaha, 1,100 to 1,300 pounds (dollars per hundredweight).

P_{c_3} = price of Good slaughter steers at Omaha, 900 to 1,100 pounds (dollars per hundredweight).

P_{c_4} = price of Prime slaughter steers at Omaha, 1,100 to 1,300 pounds (dollars per hundredweight).

P_{c_5} = price of Choice slaughter heifers at Omaha, 800 to 1,000 pounds (dollars per hundredweight).

P_{c_6} = price of Good slaughter heifers at Omaha, 700 to 900 pounds (dollars per hundredweight).

The standard errors of estimate are 27, 47, 64, 42, and 60 cents per hundredweight, respectively.

The coefficients of determination suggest strong substitution forces between the various weights, grades, and classes, indicating efficient performance in the price mechanism at the slaughter level. The constant terms and regression coefficients generally indicate price premiums paid for weight and quality differences in the heavy Choice and Prime grades. Discounts were evident in the Good grade and heifer classes. Improvements in the estimating technique, by using an error-in-variable model, could improve the consistency of the regression slope and intercept values. For purpose of forecasting, the above estimating equations accurately measure the price differentials for weight, grade, and class.

Slaughter Hog Prices by Weights and Locations

The price for 220- to 240-pound slaughter hogs on the Omaha market served as the basis for the analysis. In an efficient market the price relationships should reflect the relative yields and resulting premiums or discounts for each weight class. Differences in price between locations, for the same weight class, should be equal to the differences in transportation cost between the locations and a common outlet. The equations estimated monthly from 1957 to 1966 are as follows:

$$(18)\quad P_{h_2} = -0.09246 + \underset{(0.00154)}{1.00708}\,P_{h_1} \qquad r^2 = 0.999$$

$$(19)\quad P_{h_3} = -0.19895 + \underset{(0.00662)}{0.99157}\,P_{h_1} \qquad r^2 = 0.995$$

$$(20)\quad P_{h_4} = -0.38904 + \underset{(0.01950)}{0.89066}\,P_{h_1} \qquad r^2 = 0.946$$

$$(21)\quad P_{h_5} = -0.28552 + \underset{(0.00580)}{1.00124}\,P_{h_1} \qquad r^2 = 0.996$$

$$(22)\quad P_{h_6} = 0.36762 + \underset{(0.00593)}{0.97938}\, P_{h_1} \qquad r^2 = 0.996$$

$$(23)\quad P_{h_7} = 0.53809 + \underset{(0.00701)}{0.97951}\, P_{h_1} \qquad r^2 = 0.994$$

where

P_{h_1} = price of No. 1-3 slaughter hogs at Omaha, 220 to 240 pounds (dollars per hundredweight).
P_{h_2} = price of No. 1-3 slaughter hogs at Omaha, 200 to 220 pounds (dollars per hundredweight).
P_{h_3} = price of No. 1-3 slaughter hogs at Omaha, 240 to 270 pounds (dollars per hundredweight).
P_{h_4} = price of No. 1-3 slaughter sows at Omaha, 330 to 400 pounds (dollars per hundredweight).
P_{h_5} = price of No. 1-3 slaughter hogs at St. Paul, 220 to 240 pounds (dollars per hundredweight).
P_{h_6} = price of No. 1-3 slaughter hogs at St. Louis, 220 to 240 pounds (dollars per hundredweight).
P_{h_7} = price of No. 1-3 slaughter hogs at Indianapolis, 220 to 240 pounds (dollars per hundredweight).

The standard errors of estimate are 6, 25, 74, 22, 23, and 27 cents per hundredweight, respectively. The values of r^2 for the above equations indicate that strong competitive forces exist in the bidding for slaughter hogs. The evidence supports an efficient performance by the price mechanism at the slaughter level. The prices paid for 220- to 240-pound hogs at Omaha explain from 95 to 99 percent of the variation in the prices of hogs for various weights, classes, and location. The regression coefficients and constant terms accurately reflect yield and price differentials for grades and weights of slaughter hogs. In the location estimates, transportation cost differences per hundredweight are represented by the values of the constant terms. The constant terms tend to reflect the proximity to major pork consumption centers.

Feeder-Slaughter Cattle Price Relationships

Analysis of the prices paid for feeder animals and their eventual slaughter price requires lagging the price of feeder animals equivalent to a period of time necessary to fatten the animal from feeder weight to slaughter weight. The price of 901- to 1,100-pound Choice slaughter steers at Omaha was chosen as the base price. Theoretically, if orderly equilibrium producing decisions were being made and were reflected in the price structure, the regression coefficients and the constant terms should reflect cost of gain and feeding efficiency margins between the feeder and slaughter prices. Feeding costs were generally constant over the period so no feed price was used in the functions. The relationships were estimated using average monthly prices from 1957 to 1966 as follows:

$$(24)\quad P_{f_{2t-3}} = 9.08457 + \underset{(0.08627)}{0.53576}\, P_{c_{1t}} \qquad r^2 = 0.246$$

$$(25)\quad P_{f_{3t-4}} = 11.59478 + \underset{(0.10504)}{0.47352}\, P_{c_{1t}} \qquad r^2 = 0.147$$

$$(26)\quad P_{f_{4t-6}} = 17.10627 + \underset{(0.12893)}{0.32310}\, P_{c_{1t}} \qquad r^2 = 0.050$$

where

$P_{c_{1t}}$ = price of Choice slaughter steers at Omaha, 901 to 1,100 pounds (dollars per hundredweight).
$P_{f_{2t-3}}$ = price of feeder steers at Omaha, 801 to 900 pounds, lagged 3 months (dollars per hundredweight).
$P_{f_{3t-4}}$ = price of feeder steers at Omaha, 701 to 800 pounds, lagged 4 months (dollars per hundredweight).
$P_{f_{4t-6}}$ = price of feeder steers at Omaha, 501 to 700 pounds, lagged 6 months (dollars per hundredweight).

The standard errors of estimate are \$1.94, \$2.34, and \$2.84 per hundredweight, respectively. The values of r^2 are extremely low in all three equations. If production and marketing were orderly, the base slaughter prices for 900- to 1,100-pound steers should be expected to explain at least 80 percent of the variations in prior feeder steer prices. The values of r^2 on each of the estimating equations indicate that the lighter the feeder steer the less consistent is the evidence.

If the marketing system for feeder animals were performing efficiently, the regression coefficient would be approximately the ratio of slaughter to feeder weight, and the constant term would reflect the average supply cost per hundredweight of moving the animal from a feeder class to a slaughter class. However, in the above three equations, none of the regression coefficients or constant terms consistently reflect these relationships—the lighter the feeder animal, the greater the distortion from the expected value. The estimates indicate that prices paid for feeder animals are not based on expected future slaughter price, but rather on the existing slaughter price at the time of the feeder animal purchase. Also, aggregate industry decisions produce levels and marketing patterns which are inconsistent with continuous dynamic equilibrium (*5*, pp. 9-12; 49-55).

If the previous three equations were estimated without lags, the results would indicate the influence of existing slaughter prices on the bidding for feeder animals. The relationships were estimated in the same way as the previous equations, with the exception of the lags, and are as follows:

$$(27)\quad P_{f_{2t}} = -0.51070 + \underset{(0.04920)}{0.93168}\, P_{c_{1t}} \qquad r^2 = 0.752$$

$$(28)\quad P_{f_{3t}} = -1.16446 + \underset{(0.06496)}{0.99561}\, P_{c_{1t}} \qquad r^2 = 0.666$$

$$(29)\quad P_{f_{4t}} = -1.39168 + \underset{(0.08290)}{1.07438}\, P_{c_{1t}} \qquad r^2 = 0.587$$

The prices paid for feeder animals seem to be influenced more by current slaughter prices than by expected slaughter prices (or expected prices are strongly based on current prices), since the r^2 values are considerably higher in these latter estimates. However, the relationships are not strong enough to support the conclusion that feeder prices are based solely on existing slaughter prices. The evidence does show, however, that existing slaughter prices strongly influence the prices paid for feeder animals. Consequently, one must conclude that the greatest degree of disorderly performance is in the time dimension between the ranch and feedlot levels.

Implications

The relationships in the preceding analyses reflect strong competitive forces which produce efficient performance from the slaughter to the retail level. This would indicate that improvements in production and marketing of cattle and hogs to the slaughter level could yield substantial industrywide payoff.

Relationships between the prices of slaughter and feeder cattle were found to be very weak and distorted. Results indicated that prices paid for feeder animals did not reflect their future value as slaughter animals. Because feedlot operators were unable to correctly anticipate future slaughter prices, ranchers and feeders alternately received windfall gains or suffered losses.

Besides the price system's role as a mechanism of trade, it must also serve as a signal for producers to organize the level and timing of future production. If producers cannot correctly estimate future production levels and resultant prices, they may cause aggregate over- or under-production.

An inherent biological problem in the beef-pork sector is the length of the production process. In beef production it may take from 2½ to 4 years from the time a production decision is made until eventual marketing as a slaughter animal. In pork production, the time required is from 9 months to a year. Short-run adjustments in marketings can be implemented much faster due to the ease of slaughter or of carrying animals to heavier weights. The problem therefore becomes one of establishing long-run production levels to meet expected future demands, and then allowing for short-run adjustments in marketing as the animal reaches the slaughter point, to correct for errors in the production level.

Hopefully, both performances could be made consistently optimal. The inefficient production and marketing performance is a problem for the industry rather than for individual firms. But effective solutions will require critical thinking by all who are interested in the welfare of those working in and served by the beef-pork industry.

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BOOK REVIEWS

Producer Power at the Bargaining Table: A Case Study of the Legislative Life of S. 109

By Randall E. Torgerson. University of Missouri Press, Columbia. 328 pages. 1970. $9 cloth, $6 paper.

This is an important book. It deals with the most pressing problem facing American agriculture: Who will control farming?

The author, Randall E. Torgerson, agricultural economist, University of Missouri, is well qualified to help answer this question—by family background, interest, training, and experience.

S. 109 became law in 1968 as "The Agricultural Fair Practices Act of 1967." In his preface the author states that his book "is a case study of the legislative life of Senate Bill S. 109 and the changing power structure surrounding farm legislation in Washington." Following the lead of John R. Commons, Charles M. Hardin, and other institutional thinkers, Torgerson focuses attention on pressure groups as "determinants of economic and social behaviour." He maintains that "from the blow by blow account, the student of legislative process and farm policy should gain valuable insights into the interaction of economic pressure groups."

This review makes no attempt to summarize, for the study calls for reading and reflection if one would understand its meaning. The value of the book is in its sustained cumulative analysis of an important problem, and its realistic portrayal of forces and men at work on divergent goals. A significant feature is its frank description of the behavior of those who participated in the struggle for or against this measure, and the assessments of their changing positions.

S. 109 grew out of the problem of farmers in their search for equality of bargaining power with processor buyers of their products. It represented an attempt by law to gain protection from unscrupulous and unfair practices which made a travesty of their so-called right to bargain. Their champion in the legislative field was the American Farm Bureau Federation. The AFB took the lead in drafting S. 109 and getting it introduced in the Senate. But the AFB soon had two other strong allies, the National Council of Farmer Cooperatives and the National Milk Producers Federation, and as time went on other farm organizations and cooperative groups joined them. Opposed to the bill were strong lobbying interests and a "strong anticooperative contingent that testified against granting any more special privileges to farmers." Involved also were the Federal Trade Commission and the Departmement of Agriculture with several of its agencies.

In the battle—for it became that—a high point was reached in 1967 when farmer and cooperative interests largely coalesced in support of a modified Farm Bureau measure. However, under pressure dissension developed among the protagonists and support soon neared collapse. How the bill survived and at what cost is well described in this book.

In introducing the bill in 1966 which became S. 109, Senator George Aikin, author of the bill and its chief proponent through its legislative life, said: "This bill does not in any way grant special privileges to farmers, to farmer cooperatives, or to agricultural associations of any kind. It undertakes to give them the same rights and protection as are now enjoyed by the people they have to deal with. S. 109 is nothing more or less than a fairplay bill" (p. 58). When it became law on April 16, 1968, it carried this explanatory description of purpose: "To prohibit unfair trade practices affecting producers of agricultural products and for other purposes." At first the act was described as "half a loaf" and for a time it was questioned whether it was more harmful than beneficial. However, in time the view has come to prevail that it was a first, if small, step in the right direction.

In his concluding chapter the author sets forth three fundamental issues that farm leaders will have to settle before getting new legislation: "(1) resolution of the structural and functional roles of different farm organizations; (2) determination of the proper institutional arrangements under which farm bargaining can be exercised; (3) formulation of a bargaining proposal that includes a statutory definition of bargaining associations and provides for flexibility under antitrust law, bargaining in good faith and other provisions necessary for effective bargaining."

To attain their aims the author believes that both cooperative and farm organizations must be willing to compromise, and he holds that they both have a right to "a piece of the action." He is convinced that only through a combination of both organization structures can farm operators survive as entrepreneurs (p. 231).

The discussions in this book disclose a lack of fundamental knowledge with respect to the meaning and use of cooperative organizations even by their proponents. They should go far to impress the need of homework and more knowledge based upon research by those who would support or defend the role of cooperatives in American agriculture.

In this day when agricultural economists are more concerned with the methodology and mathematics of their craft than with the basic problems of agriculture this book comes as a breath of hope. Perhaps it will encourage other young economists, along with young political scientists and young economic historians, to turn their attention to where the action is if they wish to make contributions to the future of a sound agricultural system for the United States. The pendulum has swung entirely too far from the time when agricultural economists gave agricultural policy first priority.

Joseph G. Knapp

Rural Settlement and Land Use

By Michael Chisholm. Aldine Publishing Company, Chicago. 183 pages. 1970. $2.45.

Distance to market as the main factor in agricultural location is the theme of this book. The author, a geographer at the University of Bristol, England, attempts to provide a systematic account of the importance of distance in the establishment of rural settlements and the ultimate use of land. His thesis is well illustrated with statistical data and real-world examples, particularly when he tries to support his theoretical approach with facts, as in his examination of (1) the farm and the village, and (2) the region and the world.

In determining land value and utilization, classical economic analysis has seldom stressed the factor of distance. However, Johann H. Von Thünen in the early 19th century noted that consideration of agricultural location would be invaluable for understanding the initial stages of development. In his book, *The Isolated State*, published in 1826, he formulated a variation on the classical Ricardian determination of land value in which the nature of economic rent is based on differences in the inherent fertility of the soil. Von Thünen contended that the same outcome occurs when one considers location, that is, distance to market.

Chisholm very much subscribes to the partial equilibrium approach to location analysis and Von Thünen's ideas are central to the methods he used in his studies. He readily admits that the book is no general theory of universal validity because the problem of distance is only one of many factors affecting location patterns. But at the same time, he takes exception to the practical value of the general equilibrium approach, as expounded by Walter Isard, which tends to embrace a multitude of factors, including noneconomic variables, in an effort to explain all the major features of spatial distribution.

This reviewer feels that the criticisms presented by the author with respect to the efficacy of the general approach are weak. To be sure, some of the criticisms are valid. It is true that because of the nature of its methodology, general equilibrum analysis involves much mathematical formulation which can only be understood by experts in the field. Also, it can be agreed that many assumptions have to be made which can be dubious. However, the fundamental point to consider is that the purpose of the analysis is to understand the general pattern, rather than for use as a technique to examine particular cases. The main value of an existing general theory lies in its ability to demonstrate deviations from the common rule that require explanation and which will lead to the further development of the theory.

The author believes that the virtue of the partial approach is its ability to account for what does actually occur, while the general approach involves itself in what ought to be. In essence, the partial approach is a positive position in contrast to a normative one.

The subject the author covers is large and he is to be commended for his attempt to adopt an approach that might reduce it to understandable proportions. The reader could gain much from the author's review and his case-studies application of the partial equilibrium approach, and also from the useful source material documented throughout the book.

Jack Ben-Rubin

North American Agriculture in a New World

By J. Price Gittinger. Canadian-American Committee of the National Planning Association, Washington, and the Private Planning Association of Canada, Montreal. 85 pages. 1970. $2.

The Canadian-American Committee was established in 1957 to study problems arising from growing interdependence between Canada and the United States. It is composed of 85 business, labor, agriculture, and professional leaders and is sponsored by the National Planning

Association (USA) and the Private Planning Association of Canada.

In keeping with a "North American approach in its search for constructive programs," the Committee has published *North American Agriculture in a New World*, by J. Price Gittinger, an agricultural economist with the World Bank's Economic Development Institute. Despite the exceptionally broad scope suggested by the title, this study is concerned primarily with world markets for Canadian and U.S. exports in general and with problems and policies arising from competition for the world wheat and feed grain markets in particular. In the course of discussing Canadian-American issues and possible future directions for international cooperation, this short, well-organized, and readable study packs a wealth of useful information on the role and impact of the European Common Market, the Kennedy Round, the International Grains Arrangement, growing commercial markets outside Western Europe, and—within the context of growing world food needs—the potential of new seed varieties, the population problem, and concessional sales to less developed countries. In support of his material the author frequently relied on Department of Agriculture statistics and cited Department publications.

Gittinger concludes that U.S. and Canadian agricultural export interests are mostly complementary. Only with regard to wheat is there a serious commercial conflict. This stems from such problems as differing price structures, the large number of concessional sales, and the increased blurring between "concessional" and "commercial" sales which has aroused Canadians' fears of losing their share of the market.

Though Western Europe will continue to be a major North American market area, the EEC's highly protectionist Common Agricultural Policy (CAP) will have to be reduced if North American-European trade is to continue to grow. The most important long-term shifts in European demand for North American agricultural products will arise as a result of such structural changes in European agriculture as the EEC's expansion to include the United Kingdom and its effect on the CAP, the continuing reduction of rural population, and attempts to modernize European agriculture. In view of the European trend toward feeding higher proportions of grain to livestock, an impetus will be given to increased grain imports in that area.

Food exports to Japan, Eastern Europe, and certain smaller developing countries will continue to grow significantly, though the pace at which future Canadian wheat exports to China and the Soviet Union continue is "problematical."

The author believes that despite the promise of the "Green Revolution," the magnitude of world food needs and the high rate of population growth will mean a continuing need for concessional sales over the next two decades.

In a statement that accompanied the study, the Canadian-American Committee reiterated the author's conclusion that it is to the interest of both Canada and the United States to revitalize international cooperation in the world wheat market through an instrument such as a working International Grains Arrangement. "Healthy future trade relationships mean that agricultural protectionism (and, by implication, domestic agricultural policies) must be the subject of trade discussions." Moreover, any agreement must associate both importing and exporting countries, "very likely with an explicit recognition of the place of agricultural trade in the broader context of world trade relationships."

Marion M. Montague

Food Consumption Statistics, 1954-66

Organization for Economic Cooperation and Development, Paris. 690 pages. 1968. $12.

The size of this publication by itself is impressive with 690 oversize pages of statistical tables on food consumption for 18 countries belonging to the Organization for Economic Cooperation and Development (OECD). The format is organized around a separate chapter for each country with tables for each of about 40 to 60 commodities. A table giving the nutrient value (calories, protein, fats) per 100 grams of each food and another showing total annual per capita consumption of these nutrients are also included. Each commodity table contains supply and use data and per capita consumption in grams and nutrient value. The introductory text and table headings are printed in both French and English.

Acknowledging the tremendous task of assembling and publishing this mass of statistics, we must ask, was it worth the effort? One desirable use would be the comparison of total calorie, protein, and fat intake among the countries. However, we are warned by OECD to be extremely cautious in making any such comparisons because of country differences in concept, definition, computational techniques, extraction rates, and other technical considerations.

In spite of these warnings I compared data for five countries. The nutrient values per 100 grams for a specific food varied widely among countries. For example, calories per 100 grams of pork ranged from 220 to 403 (the range would have been greater if all countries were examined). Protein content varied from 10 to 16 grams per 100 calories. Poultry yielded from 100 to 431 calories, 12 to 31 grams of protein, and 5 to 33 grams of fat. So there is reason for caution in making comparisons between countries.

Another course of investigation is the study of trends in each country and perhaps a comparison of these trends. OECD thinks this would yield valid results, although some caution is again urged. The data in the tables may not contain the latest revisions and in some cases there may be changes in concepts and definitions. Incidentally, the U.S. data do not include revisions which were published in 1968 for earlier years. Although the revisions might not seriously mislead casual readers, they represent potential pitfalls for analytical work. In addition, the size of revisions may vary widely from country to country.

Surprisingly, the changes in consumption of individual commodities and total nutrient levels seem to make sense for the five selected countries. Meat consumption increased in each country and poultry consumption increased sharply between 1955-59 and 1960-64. Wheat consumption tended to decline. Calories available, as well as proteins and fat, held steady in Canada, the United States, and the United Kingdom. In Japan and Italy they increased significantly.

As a result of these deficiencies, the main value of the publication is the consolidation of the OECD statistics and the accompanying notification that the data exist. Perhaps the member countries and the OECD Statistics Division will now make the determined effort to revise and standardize the data. Then the fruitful work of intercountry comparisons and cross-sectional analysis can begin.

Hazen F. Gale

Change and Development—Latin America's Greatest Task

By Raul Prebisch. Inter-American Development Bank, Washington. 235 pages. 1970.

This study was commissioned by the Inter-American Development Bank as a result of the failure of Latin American countries to achieve goals in rates of growth. It is designed as a master target plan rather than as a series of specific country development projects. This work outlines a plan for development of the area which would make it self-sustaining by 1980. The plan would be substantially finished by 1990. No question, the need is there.

The author's thesis is that lack of concerted internal investment effort is the reason for Latin America's slow development. He believes that internal development funds can be virtually doubled by 1980 and that it is only through an effort of this magnitude that satisfactory development can be accomplished. Most of this large increase will, of necessity, take place through decreases in the consumption of high-income groups. External cooperation is considered to be important, but only as a means of supplementing and stimulating internal action.

By 1980 agriculture will be increasing productivity at a rate of 4 percent a year. Intraregional trade in agricultural products is also scheduled to increase. As an indispensable requisite for vastly increased productivity, Prebisch would require a reform of the land tenure system. He points out that agriculture in Latin America today is carried out with a terrific waste of human potential. New agricultural techniques already in existence plus increased research in tropical agriculture will provide an economic solution for agriculture. The social techniques must be found.

During the development period large-scale efforts must be made to make up the housing deficit, increase social mobility, and improve income distribution, as well as to provide more education and health services.

The key to maintaining a growth rate of 8 percent for a 20-year period is industrialization—including the full use of installed capacity and the addition of more. To do this the region must become a fully functioning member of the world trade and industry system.

Perhaps the author errs on the side of optimism in projecting potential growth as high as he does—and maybe the desire is not strong enough for the tremendous effort that would be required—but the need is there.

I believe that he dismisses too lightly the effects of extremely high population growth on development, but that is another argument which will not be further raised here.

John D. McAlpine

The Agricultural Development of Brazil

By G. Edward Schuh. Frederick A. Praeger, Inc., New York. 441 pages. 1970. $18.50.

This welcome contribution to the bookshelf on Brazil provides (1) a concise handbook on Brazil, (2) a valuable chapter on agricultural economics, and (3) an excellent survey of agricultural education and research. Schuh prepared it under the sponsorship of the Ford

Foundation; his prescription for agricultural education will have practical value for the foundation.

This handbook is admirable for its condensation of vast materials. Although books on Brazil tend to sprawl hopelessly, the author has reduced his text to 440 pages. It is a synthesis of published materials since 1950 that attempts to give the big picture, to touch down conscientiously on population trends, the labor market, food balances, land tenure, capital investment, agricultural policy, exports, education and research, marketing, and projections. As a reference book it provides easy access to practically all published materials.

The essential chapter for agricultural economists is chapter 4, "Structure and Characteristics of Brazilian Agriculture." In tracing developments between 1950 and 1966, it defines the realities and dispels misconceptions. The author admits that southern Brazil is endowed with some of the world's most fertile soils, but stresses the basic fact that for the rest of the country, low fertility of the soils is characteristic. What a shock it is to read under "mechanization" that 76 percent of the farmers in 1960 were still "men with a hoe"! An advance for them would be a plow and a draft animal. Schuh believes that most of the published material on the latifundia problem in Brazil has been dangerously misleading. He demonstrates this by making detailed statistical comparisons for the five different regions of Brazil between the censuses of 1950 and 1960, and the cadastral survey of 1965. A picture emerges from the five different regions that differs dramatically from the aggregates of the country as a whole. Fifty-five percent of the farms in the productive south are of family size; the vast holdings of the sparsely settled north and west that distort the aggregates have little access to markets and are of little economic significance. Oversimplification would do an injustice to his demonstration, which is the best I have seen on land tenure in Brazil.

Chapter 5, "Education and Research," should be of special interest to decisionmakers in the Brazilian Government, USAID, World Bank, and the foundations. It is a definitive study that evaluates every phase of agricultural education and research and their use by the extension services. It is an inspired piece of organization that traces cause and effect from research to final results.

The book has two limitations. The author's interest in the details of crops and livestock is secondary to his interest in aggregative economics. Production statistics are perfunctory. He scants the story of the developing crops which had already set trends when the book went to press: the wheat program that succeeded in 1969, the boom in cotton production and exports in 1969, the emergence of vegetable oils such as soybeans. The moribund cocoa culture has since made a vigorous comeback. His chapter, "Other Support for Agriculture," identifies each of the government agencies that have a bearing on agriculture. If he had shown how the units of this labyrinth actually affected crop production, this service would have had far greater importance than his chapter on education. Organization is not inspired here; it's a basket category. Although he gives the basic limitations of the livestock economy, the slaughter-herd ratios, the low carcass yield and low fertility rates, coverage of livestock is even weaker than that of crops.

The date of the material is the other limitation. Some statistical tables go through 1966 and 1967, but the bulk of the material refers to the problems of the Goulart regime which was over-thrown in 1964. The effects of the new policies were not sufficiently clear, even in 1966. Since then, the new government has made remarkable strides with more enlightened agricultural policies in credit, price supports, fertilizer manufacture, and crop diversification. The elimination of trade controls led to a surge in exports, most of which are agricultural, of 13 percent in 1968 and 22.5 percent in 1969. New nontraditional exports such as corn, rice, soybeans, and chilled beef have set records. The dramatic development of the late 1960's remains to be written.

Samuel O. Ruff

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